# Chemical Constituents vs. Water Quality

G. FRED LEE, Ph.D., P.E., D.E.E.
and
ANNE JONES-LEE, Ph.D.

Dr. G. Fred Lee is president and Dr. Anne Jones-Lee is vice president of G. Fred Lee & Associates, a specialty environmental consulting firm located in El Macero, California.

Part One of this article discussed the problems with current stormwater runoff water quality monitoring programs and suggested the values of alternative monitoring approaches. Part Two continues the discussion with specific examples from San Francisco Bay and Santa Monica Bay.

THE copper situation in San Francisco Bay provides an excellent example of the relative merits of the highly directed evaluation monitoring program designed to identify real problems vs. the traditional monitoring program focusing on chemical constituents. A number of the stormwater dischargers to San Francisco Bay have conducted one- to several-year studies of the various discharges to the Bay, which cost many tens of thousands to $100,000 or more. In these studies, the traditional approach of monitoring a suite of parameters in the discharge waters and some of the source waters to the discharge were conducted. While large amounts of data on the chemical characteristics of the stormwater discharge waters were generated by this approach, such an approach provides no useful information on water quality impacts that were not available before the study was conducted.

It was known before the studies were conducted that runoff from urban areas and highways in the San Francisco Bay region have a variety of chemical constituent concentrations above water quality standards. Whether these exceedances of the standards, however, represent a real use impairment that affects the numbers, types, and characteristics of aquatic organisms in the Bay has not been determined by these types of studies. Further, while as discussed previously these are often called stormwater runoff discharge characterization studies, they fall far short of properly characterizing the discharge, since the purpose of discharge characterization is to find pollutants. These studies define chemical constituent concentrations and do not define pollutants, i.e. those constituents that do, in fact, impair the designated beneficial uses of the receiving waters for a particular discharge on a site-specific basis.

It is totally inappropriate to use the approach that is often done by those not knowledgeable in aquatic chemistry, aquatic toxicology, and water quality of assuming that because copper from some source, such as a plating waste, is toxic to aquatic life in some waterbody and is therefore adverse to the beneficial uses of that waterbody, then all copper from all sources is adverse to the designated beneficial uses of all waterbodies. Such an approach is similar to characterizing all people with red hair as having certain personality traits. It is obviously technically invalid.

Another example of the relative merits of the evaluation monitoring approach for monitoring stormwater impacts is provided by San Francisco Bay. As noted above, the large-scale studies conducted by a number of stormwater dischargers on the characteristics of the stormwater discharges to San Francisco Bay, while determining to some extent the amounts of copper and other constituents entering the Bay, provided no information on the impact of these constituents on the beneficial uses of the Bay waters.

By focusing on defining Bay water quality problems, first through the use of toxicity measurements on ambient waters, it has been shown that there is no toxicity in San Francisco Bay waters due to all constituents derived from stormwater runoff and other sources. Therefore, copper and all other constituents are not causing a toxicity problem in San Francisco Bay, and there is no technically valid need based on current information to control copper inputs from urban stormwater runoff as well as other sources to the Bay because of the exceedances of the water quality objectives for copper in the Bay waters.

Some recent data generated on the northern part of San Francisco Bay show that there may, in fact, be a toxicity problem due to pesticide runoff. This is an area where the evaluation monitoring approach could help determine whether this is a potentially significant problem. If significant, the specific cause of the problem and the source responsible for contributing the toxicants can be identified. At that point, specific source controls can be initiated to prevent this problem from occurring in the Bay and its tributaries.

It would have been far more technically valid and cost-effective to screen San Francisco Bay waters for toxicity problems first and then, if found, identify the cause of the problems, than the approach that has been followed and is going on today to collect in routine monitoring programs large amounts of data on stormwater discharge characteristics that focus on chemical constituents rather than water quality issues.

### Santa Monica Bay Studies

The deficiencies of the mechanical, unintelligent, traditional monitoring approach can also be demonstrated by the situation that has developed in the Santa Monica Bay Restoration Project where in September 1994 the management of that project, which included local, regional, and state agencies and the EPA, committed the public to spending $40 million over the next five years to implement structural BMPs for control of chemical constituents, principally heavy metals, in stormwater runoff from the Santa Monica Bay watershed.

A review of the technical base for this so-called restoration program shows that the traditional monitoring approach was used where the total concentrations of chemical constituents and the stormwater flows from the Santa Monica Bay watershed were used to develop a mass load of heavy metals and a few other constituents of potential concern into the Bay.1 Since the heavy metals are conservative and are largely associated with particulates, these metals settle in the Bay waters and become part of the sediments, resulting in elevated concentrations of heavy metals in the sediments compared to areas that are not impacted by runoff from the Santa Monica Bay watershed.

It was assumed, based on fundamentally flawed principles, that because elevated concentrations of certain heavy metals that are present in stormwater runoff from streets and highways accumulated in the sediments of Santa Monica Bay, this must represent a significant adverse impact on Santa Monica Bay's designated beneficial uses through these heavy metals being toxic to aquatic life. However, no toxicity measurements were made before committing the public to the $40-million restoration program to verify that toxicity was even present in the sediments, and if present that it was due to heavy metals, and if due to heavy metals that these heavy metals were derived from current urban stormwater inputs to the Bay.

Rather than spending large amounts of money, as was done in the Santa Monica Bay Restoration Project, on defining the amounts of the mass loads of heavy metals and a few other constituents entering Santa Monica Bay, the focal point of an intelligent monitoring program would have been to determine whether there is a real water quality problem in Santa Monica Bay due to current inputs of constituents from all sources. Is there toxicity in the Bay water column and/or is there toxicity in the Bay sediments? These are the questions that should have been asked first. If toxicity is found in either the water column or sediments, is this toxicity of significance to the beneficial uses of the Bay? If it is found to be of significance to beneficial uses of the Bay, what is the cause of the toxicity? If it is due to heavy metals, are these heavy metals derived from current urban stormwater runoff to the Bay? If it is found that current heavy metal inputs from stormwater runoff are causing toxicity in the receiving water sediments, then what is the specific source of the toxic heavy metals that have ultimately accumulated in the sediments?

It is totally inappropriate to assume that all sources of copper result in the same toxicity in sediments independent of the source. Copper from Mercedes brakepads that will accumulate in Santa Monica Bay sediments will likely have significantly different toxicity to aquatic life than copper derived from its use in a sewer to control excessive root growth within the sewer which tends to plug up the sewer. Both will be contributed to Santa Monica Bay—one through the wastewater discharges, the other through stormwater runoff.

The approach used in the Santa Monica Bay Restoration Project for developing the basis for defining a stormwater runoff-associated water quality problem is rapidly becoming recognized as a highly technically invalid approach that has a high probability of resulting in massive waste of public and private funds in developing structural BMPs to achieve an ill-conceived mass load emission strategy for heavy metals from the Santa Monica Bay watershed. This ill-conceived approach arose out of failing to conduct a reliable stormwater runoff water quality evaluation monitoring program.

### Mechanical vs. Intelligent

Basically, the development of a monitoring program for stormwater runoff that focuses on water quality through periodic measurement of chemical constituents comes down to choosing between a mechanically implemented approach, which is the approach typically followed today, vs. an intelligent monitoring program, which focuses on first defining a real water quality problem independent of the source and then when found, using the limited monitoring resources available to focus on finding the role that stormwater dischargers of constituents play in causing the problem. This is followed by focusing the monitoring program on defining and controlling the cause of the problem.

While some will correctly claim that the approach advocated does not define all possible problems, especially the very subtle problems associated with yet unidentified, unregulated chemical constituents that are not manifested in toxicity to the sensitive forms of aquatic life used to establish the water quality criteria exceedances in the stormwater discharges of concern, this approach does focus resources on defining the most important causes of the use impairment, and can, if properly carried out, provide the biggest bang for the buck in terms of solving real use impairments in the receiving waters for the discharge. By allocating small amounts of funds for ongoing studies to identify more subtle problems associated with any major discharge, it is possible through these ongoing water quality problem definition studies to refine the initial studies to include some more subtle effects associated with stormwater discharges. The more subtle effects may be due to unrecognized problems that may be found but not yet identified, or due to the introduction of new chemicals into the urban environment, such as a new pesticide or herbicide used on lawns, a new additive to gasoline, a new material incorporated into brakepads that would replace copper that somebody considered was adverse to receiving water quality because it was simply copper without considering its speciation and whether it was toxic-available or not, etc.

As proposed, the evaluation monitoring program should define and rank the significance of all potential water quality use impairments of a waterbody that receives stormwater runoff from a particular source. This should be a cooperative program between the stormwater dischargers, the water quality regulatory agencies, the public, and others interested in water quality in a particular waterbody. It should be repeated for each of the types of water quality use impairments at least once each NPDES permit period (five years).

The problem definition evaluation monitoring studies should be conducted in a tiered hazard assessment approach in which through an integrated use of aquatic chemistry, which includes transport-fate and aquatic toxicology information, it is possible to define to various degrees of each tier whether a potentially significant water quality problem exists or not, associated with a stormwater discharge. Many problems can be eliminated from further consideration at the early tiers and thereby greatly reduce the cost to the public of conducting the monitoring program. It is important to emphasize that the focus of these efforts is to define the most significant impacts of stormwater discharges first and control these while continuing to provide funds to try to find more subtle impacts which, if they are found, can then be addressed in a similar manner. This approach is a far more technically valid, cost-effective approach for the use of public and private funds in developing stormwater quality programs than those typically being followed today.

### Funding Evaluation Monitoring

There is increasing recognition that funds currently being used for end-of-the-pipe pavement, property monitoring of stormwater runoff should be shifted at least in part, if not totally, to evaluating the impact of the stormwater runoff on receiving water quality. It is recommended that stormwater quality managers and regulatory agencies work together in funding the evaluation of the impact of stormwater runoff-associated constituents on the receiving waters' beneficial uses. In situations where there are multiple NPDES stormwater-permitted dischargers to a particular storm sewer system, including industrial and commercial sources, each of the permitted dischargers should work with the regulatory agencies and the public in pooling the financial resources available to define, on a site-specific basis, the significant water quality problems caused by a stormwater runoff. This approach will lead to a far more technically valid, cost-effective control of real water quality problems caused by urban area and highway stormwater runoff than is being achieved today.

There is also need to expand the regulated stormwater community to include smaller communities and especially agricultural and forest interests. All entities contributing stormwater runoff should be responsible for defining the water quality impacts of the constituents in the runoff on the beneficial uses of the waters in a particular watershed. The evaluation monitoring approach is particularly useful for implementing a technically valid, cost-effective watershed management approach for water pollution control.

### Active vs. Passive

The authors[2] have discussed the relative merits of what they call active vs. passive water quality monitoring. The traditional approach of water quality monitoring involves the periodic sampling of the discharge and/or receiving waters where each sample is analyzed for a suite of parameters for a fixed period of time. At the end of this period an attempt is made to develop inference about water quality issues from the data set. This approach is the passive approach which often proves to yield information of non-definitive and sometimes highly questionable quality. In the Lee and Jones active water quality monitoring program, the data are examined as they are collected to evaluate their reliability and to ascertain to the extent possible the real water quality information available in the data.

In the active approach, the water quality evaluation monitoring program is an evolving program that is adjusted to match the characteristics of the system being studied. As discussed by the authors[3], the characteristics of the system being monitored should be sufficiently well understood so that the monitoring program is specifically tailored to investigate those parameters likely to cause water quality impairment. While a periodic monitoring program that is either time or event driven can serve as a backbone for the active monitoring program, often special-purpose, highly specific, short-term studies are key components of the active program to further investigate within a short period after a data collection event shows a potential impact that needs to be further defined. The active water quality monitoring program is in accord with the recommendations of the National Research Council review panel devoted to developing guidance on assessing water quality problems.[4]

The authors[2,3] recommend that an active monitoring program be used where the overall program design is formulated to match the variability and characteristics of the system being studied. Further, the data are analyzed as they are being collected for consistency, reliability, and information on water quality issues. The sampling program is adjusted to take into account the new information that is gathered through the studies.

## Source Identification

One component of stormwater runoff water quality evaluation monitoring that needs attention is the identification of pollutant sources. The typical approach today in such monitoring is the shotgun approach, in which a wide variety of chemical constituents are measured at various locations in a stormwater runoff discharge watershed to attempt to determine what specific activities or entities within the watershed are responsible for the pollutants found in the discharge. While not addressed by this type of monitoring, obviously the first step in a technically valid pollutant identification monitoring program is identifying the real pollutants that are adversely impacting the designated beneficial uses of the receiving waters for the stormwater runoff.

The shotgun approach for pollutant source identification is usually highly wasteful of public and private funds and often not reliable. About all that can be said of such programs is that a constituent of concern, such as copper, is derived from various sources to certain degrees. However, no information is provided as to whether copper is, in fact, a real pollutant and most importantly, what source is responsible for that part of the copper that causes the pollution-use impairment in the receiving waters for the stormwater runoff. It is certainly highly inappropriate to assume, as is often done, that all copper from all sources is equally adverse to the designated beneficial uses of a waterbody. Such an approach ignores the aquatic chemistry and toxicology of copper that are important in determining the extent that copper impacts the designated beneficial use of the waterbodies.

In the evaluation monitoring approach, once a specific water quality problem has been identified it is then possible through combining selected chemical, toxicological, and other measurements, such as aquatic life toxicity for potentially toxic chemicals, to use a forensic study program to specifically identify the source(s) of the chemicals causing the water quality use impairment. Based on this identification, site-specific BMPs can be developed to control the constituents of concern at the source in the most technically valid, cost-effective manner. This issue is discussed further in the reviews by Lee and Jones-Lee.[5]

## Monitoring Hazardous Waste

Stormwater quality management agencies are finding that they must consider the management of stormwater runoff-associated residues, particularly sediment solids that accumulate within the stormwater treatment or runoff conveyance system. Environmental activist groups such as NRDC are asking the courts to force stormwater management agencies, such as highway departments, to undertake highly expensive removal of particulates that accumulate in stormwater inlet structures because these particulates are classified as "hazardous waste." There is a general lack of understanding of the basis for such classification and the relationship between classification of a settled solid associated with highway and street runoff as a hazardous waste and the impact of that solid on water quality in the receiving waters for the runoff. The classification of a solid material as a hazardous waste may not, and frequently does not, mean that the chemicals associated with the solid are hazardous to aquatic life.

The chemicals associated with solids-particulates are generally recognized as being nonhazardous to aquatic life. To be hazardous to aquatic life it is necessary that the chemical constituents associated with the solids are released from the solid, i.e. dissolved. A key factor controlling the dissolution of chemical constituents from solids is pH. More acidic conditions tend to promote greater dissolution. The hazardous waste definitions used at the federal and state levels are designed to mimic the acid conditions that occur in municipal landfills and use testing procedures that involve far more acidic conditions than the solids in the stormwater runoff will normally encounter in the receiving waters for the runoff. This is especially true for stormwater discharges to marine waters. Therefore, even if stormwater-associated particulates are classified as a hazardous waste based on municipal solid waste-based leaching tests, this does not mean that the chemical constituents will be adverse to aquatic life in receiving waters for the stormwater runoff.

California, under Title 22, is one of the few states that in addition to classifying hazardous waste based on its expected behavior in a municipal solid waste landfill through the use of an acidic leaching test, also classifies hazardous waste based on the total content of constituents. This approach is of highly questionable validity since it does not properly consider the environmental chemistry and toxicology of the constituents associated with the solid material. This could lead to highly arbitrary, very expensive management approaches for stormwater-associated contaminants that accumulate in detention basins, stormwater conveyance structures, etc.

The best defense for a stormwater management entity to follow in protecting itself and those it represents against inappropriate actions that assert that solid associated contaminants are a hazardous waste and therefore must be hazardous to aquatic life in the receiving waters for the stormwater runoff is to conduct problem definition focused stormwater runoff evaluation monitoring. By demonstrating that there are no real water quality problems associated with the particulates in the stormwater runoff in the receiving waters for the runoff, it would be possible to avoid the waste of public and private funds in unnecessary management of stormwater runoff-associated particulate constituents that accumulate in the stormwater conveyance system. Site-specific studies can be highly cost-effective in assisting the stormwater management entity in focusing its limited resources in developing control programs that address real water quality problems rather than those that arise out of the inappropriate use of hazardous waste definitions.

## Effectiveness of BMPs

Stormwater management entities are being required to develop monitoring programs to evaluate the effectiveness of the BMPs that are implemented to control stormwater pollution. The typical approaches used today in this area focus on chemical constituent monitoring and are frequently expensive since a wide variety of chemical constituents are measured periodically. This is more of the shotgun approach that ignores how chemical constituents in stormwater runoff impact the designated beneficial uses for the runoff. As discussed by the authors[5,6], the development of a best management practice to control stormwater-caused pollution of a waterbody requires, as the first step, de-



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fining the pollutant(s) in the stormwater runoff. It is certainly inappropriate to assume that a stormwater detention basin, grassy swale, etc. is, in fact, removing pollutants. Such "BMPs" remove chemical constituents that in most situations are not pollutants.

It is evident that the development of a technically valid, cost-effective monitoring program for BMP efficacy must be based on a proper definition of pollutants and focus on how the BMP influences the beneficial uses of the receiving waters for the stormwater runoff. Without a reliable definition of pollutants, the monitoring program will likely be a waste of public and private funds and serve only the purpose of developing file cabinet fodder that meets the regulatory requirements for some type of monitoring program, but has little or no relevance to real issues of concern in evaluating the efficacy of the BMP.

### Recommended Approach

The most cost-effective, technically valid approach for defining water quality impacts of potentially toxic chemical constituents in stormwater runoff is to focus on defining a problem in the receiving waters that could in some way be attributable to stormwater runoff-associated constituents. There are basically two types of problems of concern. One is toxicity to aquatic life, which adversely affects the numbers, types, and characteristics of the desirable aquatic organisms in the receiving waters for the stormwater runoff, and the other is excessive bioaccumulation of chemicals that are potentially toxic to higher trophic levels that use aquatic organisms that have accumulated constituents from the water as a source of food. A higher-level-trophic organism can be man, where the concern is carcinogens such as from chlorinated hydrocarbon pesticides, PCBs, dioxins, PAHs, etc.

While the EPA and others somewhat arbitrarily attempt to distinguish between monitoring for assessment of impact and characterization of stormwater discharge, such a distinction is inappropriate. There is no point in chemically characterizing a stormwater discharge from urban area and highway runoff, as is typically done today. The chemical characteristics of these discharges are well known. A proper discharge characterization must include impact evaluation since the purpose of discharge characterization is the definition of pollutants, i.e. those constituents that on a site-specific basis impair the designated beneficial uses of the receiving waters for the discharge.

One issue that frequently develops with departments of public works or other stormwater management entities who now are responsible for stormwater quality management, is the appropriateness of such departments funding stormwater impact studies. Some public works directors take the attitude that this must be done by the regulatory agencies or others. Such an approach is short-sighted and contrary to the best interests of the stormwater management agencies and the public they represent. If the stormwater management agency does not define impacts, then no one else will. Or if they are defined by others, they will likely attribute a far greater impact than actually occurs because of the number of chemical constituents that exceed water quality standards in urban and highway stormwater discharges.

It is the authors' experience that normally regulatory agencies adopt a somewhat overprotective approach in regulating point and non-point source discharges under conditions where reliable data are not available to show that a more technically valid, cost-effective management approach is possible. While this situation has existed for many years, with Clean Water Act citizen suits against regulatory agencies and/or dischargers becoming commonplace, such as the NRDC suits against Caltrans, Los Angeles County, City of Los Angeles, etc. for failing to adequately implement the NPDES stormwater discharge permit, it is in the best interest of stormwater dis-

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chargers to conduct the necessary studies to define what, if any, real water quality problems are occurring because of the chemical constituents in the stormwater discharge. By defining real water quality problems it is possible to focus available resources on their control rather than taking a technically invalid approach of trying to control every potential problem that could arise because stormwater runoff contains total concentrations of a variety of chemical constituents that from some sources other than stormwater runoff are adverse in some waterbody to the beneficial use of that waterbody.

Basically, today's mechanical approach toward monitoring chemical constituents in stormwater runoff is largely a waste of public and private funds since it does not define the impacts of the discharge-associated constituents on the designated beneficial uses of the receiving waters. Evaluation monitoring focusing on problem definition, while not traditional, is without question far more technically valid and cost-effective in developing the information needed by regulatory agencies, stormwater management entities, etc. in defining the approach that should be used to manage water quality impacts of stormwater discharges where real, significant adverse impacts are identified. □□□

The authors have developed a number of papers and reports that provide additional information on the evaluation monitoring approach for stormwater runoff and its implementation. These publications contain numerous references to the literature that discuss the need for and the characteristics of the approaches that should be used in evaluation monitoring. Copies of the authors' papers and reports, some of which are listed below in the references, are available upon request. Please contact: Dr. G. Fred Lee, 916/753-9630, FAX: 916/753-9956, e-mail: gfredlee@aol.com. The authors have established a web page (http://members.aol.com/gfredlee/gfl.htm) which lists many of their stormwater runoff quality related papers. A number of these papers are directly downloadable from this page.

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